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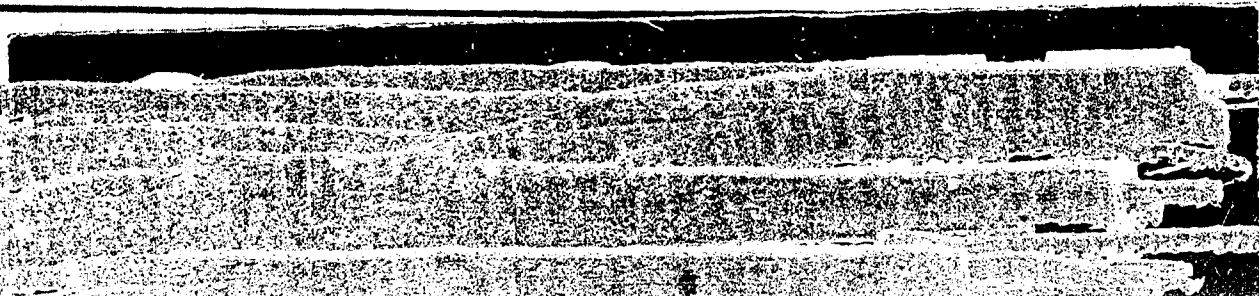
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PROPOSALS FOR CODAER  
(COMBAT DATA EXCHANGE RELAY)



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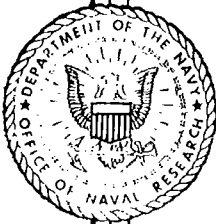
**PROPOSALS FOR CODAER  
(COMBAT DATA EXCHANGE RELAY)**

**Paul C. Sherertz**

**April 22, 1949**

**Approved by:**

**Mr. J. E. Meade, Head, Radar I Branch  
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## ABSTRACT

The basic informative and executive processes necessary for the efficient conduct of combat operations are considered to be the following:

- Intelligence - The collection and evaluation of tactical information on all enemy and friendly activity.
- Communications - The orderly exchange of combat data between all friendly units.
- Operations Control - The control of specific combat functions by coordinated evaluation of pertinent tactical information.

Mechanization of these functions into a single integrated system requiring only human supervisory control is necessary for the most efficient coordination of combat operations involving large numbers of ships, planes, and ground forces.

It is proposed to achieve automatic performance of combat functions by conversion of all requisite information at its source to a form suitable for direct insertion, transmission, selection, and utilization by electronic devices. Digital pulse coding and time multiplex transmission of data components is such an intelligence medium. To provide tactical information of quantity and quality proportional to the magnitude of operations, it is proposed to sum up all intelligence in an inter-unit combat data exchange relay which can distribute data and plot information to all craft in a given area. Electronic digital computers using the information of the data exchange may be employed to coordinate the reporting of radar information and to provide automatic control of operations. To simplify the flexible inter-connection of equipment within a given unit, it is proposed that shaft position information of directors, computers, weapons, and associated equipment be coded and entered in time sequence to an intra-unit data exchange.

## PROBLEM STATUS

These proposals were made in July 1948 following a study of the Naval AA target designation problem under R02-20, now closed. A survey of target information handling by digital methods, applicable to these proposals, is now being conducted under Problem R07-36R.

## AUTHORIZATION

NRL Problem R02-20, now closed.

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## PROPOSALS FOR CODAER (COMBAT DATA EXCHANGE RELAY)

### INTRODUCTION

Any solution for target designation, which is in actuality AA weapon coordination, that does not apply to the most complex combat operations cannot be considered to be more than a temporary expedient. The defense of combined air, sea, and land operations from saturation level air attacks is one of the most difficult combat problems, and it is instructive to consider the nature of the forces involved. It is entirely probable that under such conditions, a hundred or more ships, several hundred planes and a large number of mobile and fixed shore combat units might be concentrated within an area of 50 miles radius. For optimum AA fire coordination and air intercept control, it is essential that the identity, location, and activity of each friend and enemy craft be made known to the target designation and air control facilities. With radar screens cluttered with 500 to 1000 echoes and voice communications as the only means for inter-ship exchange of information, it is obvious that the best present organizations and procedures cannot adequately cope with the situation. It seems, in fact, necessary to devise completely new methods for evaluating and distributing tactical information before practical and satisfactory solutions to specific combat operations such as AA fire coordination or air intercept control can be developed. This report presents proposals for what is considered to be a general system for data distribution and utilization potentially capable of providing tactical coordination of land, sea, and air operations.

### CODAER - Combat Data Exchange Relay

The general problem of combat coordination increases in complexity roughly in proportion to the magnitude of the forces involved. This rather obvious fact emphasizes the requirement that the traffic handling capacity of the intelligence, communications, and operation control facilities of a task force should also increase in proportion to the number of combat units. To effect this expansion in capacity, and at the same time to avoid the duplication of tasks aboard different combat units, inter-unit exchange of combat data is indicated. The nature of the data exchange should be such that it provides to all friendly units filtered tactical data on all friendly and enemy forces within specified areas and permits automatic insertion and selective indication or usage of the data by any friendly unit.

The automatic exchange of data between combat units is considered to be a general function fully equivalent in magnitude to radar or voice radio communications. It is here proposed to title this function and the associated equipment, "CODAER," which is a reduction of Combat Data Exchange Relay. The term Codaer will be used for this function throughout the rest of this report.

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A data exchange between ships, planes, and ground forces places definite specifications on the general nature of equipment for the collection and evaluation of data on the one hand, and control or coordination of specific operations on the other. Our concept of the general combat coordination functions and the means for their attainment may now be outlined.

Intelligence - the collection and evaluation of tactical information on all enemy and friendly units. Each combat unit should insert filtered tactical data to the data exchange on its own operations and on the location and activity of enemy units. By reference to Codaer information, each unit can coordinate its reporting and receive aid in evaluation of the general situation.

Communications - the orderly exchange of evaluated combat data between all friendly combat units. This is the Codaer function. The nature of the data transmission will be largely determined by the intelligence and operations control terminal equipment. In general, it will consist of coded data and possibly filtered plots.

Operations Control - the control of specific combat functions by coordinated evaluation of pertinent combat information. The operations control equipment indicated is essentially a computer which automatically selects appropriate information from Codaer data and initiates action according to parameters under manual control.

The system proposed in this report for the performance of these combat functions is intended to conform to the following general considerations:

Equipment - The system should provide automatic coordination and control of combat functions for a single ship operating alone, or for all units of a combined air-sea-land operation. Practically, this specifies that each combat unit should carry, in addition to the data exchange facilities, only that amount of intelligence and operation control equipment required for single operation. The largest system facility should be small enough to permit installation on destroyers.

Command - The system should facilitate the supervision and control of combat operations by command personnel. Exercise of over-all control should be possible from any unit tied in with the Codaer system.

Radio Communications - The Codaer link between combat units should be capable of providing tactical data on at least 500 different targets or friends. The link should be insensitive to jamming and have a high degree of security. Finally, the data provided in the exchange should be sufficiently detailed to eliminate many voice transmissions and thus generally reduce radio communications.

Since the system must handle data on hundreds of targets, the most powerful means for compressing data, reduction of space and weight requirements, and elimination of unnecessary equipment or functions must be used. Standard synchro transmission of target position in range, bearing, and elevation, for example, requires at least 20 wires. The data exchange should be capable of transmitting precision position and activity data on at least 500 targets in a single wire or radio channel. This represents a compression of over 10,000 to 1 and indicates the magnitude both of the problem and of the advantages to be realized from its solution.

## DATA TRANSMISSION MEDIUM

A combat data exchange relay is fundamentally required because it is impossible for even the largest ship to carry sufficient equipment and personnel to analyze adequately and present in detail all the information required to secure optimum coordination of its various combat functions under the most complex circumstances. Through the medium of the data exchange, the intelligence of the entire force can be summed up and presented directly to automatic evaluation and control facilities of any type. The nature of the data transmission is indicated by the amount of information to be handled and by the facility with which it can be inserted by the intelligence equipment and utilized by the operation control equipment. The desirable tactical data on each target or friend includes the following: Ground position, altitude, identification, type, motion vector, quantity, relative threat and intent of target, activity of friend, and coordination and control data. The data must be repeated at intervals short enough to allow tracking circuits to follow smoothly the gyrations of high speed air targets. This sets the minimum data repetition rate at about 5 reports per second. Better results, particularly in view of possible noise interference are to be obtained at higher rates; 30 reports per second is considered a practical minimum for design calculations.

The considerable amount of tactical data associated with each target or friend reported points to a coding scheme for conveying intelligence. Binary digital coding, for example, presents at once a powerful method of data compression, an on-off pulse-type signal well suited to regenerative relay transmission, and an intelligence medium directly applicable to electronic computers. The superiority of on-off coding, and especially binary digital coding for Codaer is in fact sufficient to recommend its adoption as the basic intelligence medium. The number of digits estimated for a tactical data report using this type of coding is given below.

<u>Intelligence</u>	<u>Probable Precision Required</u>	<u>Number of Binary Digits</u>
Report No.	1,000 choices	10
Identity & Security Code	100 "	7
Type	100 "	7
Ground Position (Relative)		
N-S Position	10,000 "	14
E-W Position	10,000 "	14
Altitude	10,000 "	14
Motion Vector		
Course	100 "	7
Speed	100 "	7
Quantity (Of Planes, for example)	100 "	7
Relative Threat & Intent of Target	100 "	7
Coordination & Control Data		
A	100 "	7
B	100 "	7
C	100 "	7
D	100 "	7
E	100 "	7
		<hr/> 129

This indicates that a total of only about 130 digits are required for highly detailed report and coordination data. Practically, more or less digits may be found desirable; consequently, it will be assumed that a maximum of 200 digits may be required in each report.

The transmission of large numbers of data reports on a single wire or radio channel can be accomplished by either time or frequency multiplex systems, or by a combination of both. The optimum arrangement cannot be selected until after considerable development of the general system. Time multiplex appears on the basis of preliminary study to require less complex terminal equipment, and is therefore tentatively recommended.

Using 1/4-microsecond pulses for the code digits, the 200 digits comprising a single data report can be transmitted in 50 microseconds. Five hundred reports may be made in 25,000 microseconds, giving a data repetition rate of 40 per second, or 666 reports may be made with a data repetition rate of 30 per second. Thus it would seem that time multiplex on a single channel can exceed the minimum requirements stipulated for Codaer. If it is found necessary in large operations to expand the data transmission facilities, two or more channels might be used, and the reports divided in some logical fashion. Alternatively, the report repetition rate might be made to vary with the actual number of reports; thus permitting indefinite expansion of the data exchange. Four thousand reports could be made, for example, at a repetition rate of 5 per second.

Tentatively, it is considered that transmission of a fixed number of data reports or channels at a fixed repetition rate is the most practical means for distributing information. For initial experimentation, it is thought that the system might use standard 525-line television sync, timing, and transmission procedures and equipment. Each line would provide an approximately 60-microsecond channel, and the system would thus have a capacity of 525 data reports at a 30-cycle repetition rate. Individual report channels (i.e., lines) may be selected by timing or counting circuits.

#### DATA REPORTING AND IFF

The collection and evaluation of data on all enemy and friendly combat units is the task of the general intelligence system. Through the use of an automatic data exchange, this task may be divided between the various friendly units so that even the most complex operations will unlikely saturate the normal intelligence facilities of individual units. In general, if each unit can collect and evaluate sufficient information for efficient single operation, the total information from many units involved in a combined operation should be more than sufficient for all control and coordination purposes.

The first step in coordinating, simplifying, and expanding the general intelligence network of a task force is to make each friendly unit automatically report itself to the data exchange. This relatively simple objective has extensive implications. First, it is of major importance because it is an IFF system that can provide automatically both identification and positive tactical data on each friendly unit. Second, it determines the basic technical and equipment features of the data exchange relay because the reporting of tactical data requires the determination of relative position and appropriate handling of transmission time effects.

The determination of relative position requires a central reference point, while the elimination of transmission time effects from a time-multiplex data-distribution system requires the assemblage and transmission of all data from one point. These two requirements may be combined in a manner which will eliminate the need for radar or other special equipment not associated with the Codaer system for determining relative position.

This may be done by having one ship or shore facility synchronize, receive, and mix reports from the various individual units, and transmit the complete combat data to all units. This single facility which may be called the Data Central, will require a data transmitter and a report receiver, while all other units will require Responders which receive the data and also transmit reports in proper timing back to the Data Central. Figure 1 shows a block diagram of the Data Central and Responder communication loop. The use of microwave frequencies and directional antennas for the receivers and transmitters of units reporting to the Data Central should improve the security and signal quality of the system and at the same time enable reporting units to measure their bearings from the Data Central by direction finding procedures. Reporting units can determine their range from the Data Central by measuring the time required for their reports to be returned in the general data transmission. It seems probable that all ships of destroyer size or larger should be equipped to act as the Data Central, while all craft to be used in combat areas should be equipped to report to the Central just as all craft are now equipped with IFF gear.

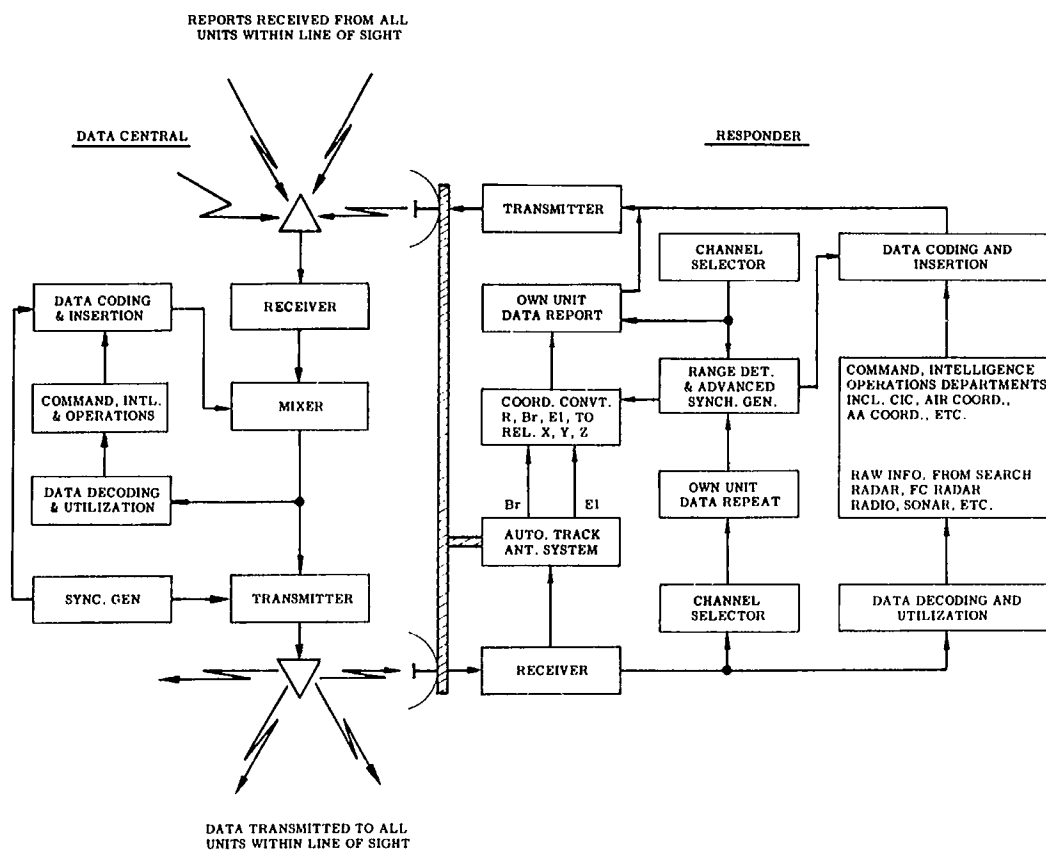


Fig. 1 - Block diagram of the combat data exchange

The use of a single Data Central for a given area makes the entire system subject to failure if the central station is damaged. At present no real solution to this problem

has been conceived. It may, however, be minimized by the designation of a standby Data Central to which all reporting craft will switch, preferably automatically, upon failure of the first. Alternately, two or more Data Centrals could be simultaneously operated on different frequencies each receiving reports from an appropriate fraction of the reporting craft, but transmitting the complete combat data through exchange of reports via special inter-central relay links. This latter procedure has much to recommend it, but will require additional equipment and frequency bands.

The insertion of data by reporting craft in correct timing on specific report channels established by the Data Central requires special procedures. Since the synchronizing pulses for the report channels are originated at the Data Central, a remote unit must advance the synchronization by the two-way transmission time between itself and the Data Central in order to insert its reports with correct timing to specific channels. The generation of the advanced synchronizing pulses can be associated with ranging circuits for determining the units' separation from the Data Central.

It is of interest to compare Codaer and its associated transmission and report facilities with IFF systems. The interrogator is comparable to the Data Central, while the transponder is somewhat similar to the data receiver, coder, and report transmitter. In the IFF system each combat unit requiring IFF data must carry and operate an interrogator and a transponder, for the transponder responses carry no position intelligence except to the particular interrogator triggering the reply. This leads to extensive cluttering of all IFF signals or "fruit" in large operations, for each radar is attempting to identify all targets. In the Codaer system the Data Central generates synchronizing pulses which are used by all other friendly units in reporting back detailed position and activity data in an orderly sequence. This data is then re-transmitted along with the synchronizing pulses to all friendly units. Since only one operating Data Central is required for a given area, it is possible to limit its installation to certain types of combat units such as ships or CIC planes and still provide all friendly units with complete IFF data. With regard to security, the presentation of detailed data in various groups and codes can provide an almost infinite number of security code combinations.

#### Target Reporting

With all friends reported automatically in the data exchange, the intelligence efforts can be concentrated on the task of detection and evaluation of enemy forces. Again, coordinated division of this function between suitably equipped planes and ground facilities should allow tactical data to be collected on all targets and entered into the Codaer system. The problems involved here include the following:

Target Selection - the selection for evaluation and insertion into the data exchange of targets not previously reported. This is a coordination problem of major proportions when hundreds of enemy and friendly combat units are concentrated within a comparatively small area. Means must be found for relating Codaer and radar information so that friends and enemies reported in the exchange can be rapidly distinguished from other radar echoes.

Target Evaluation - the evaluation of targets for relative threats. The evaluation should be as rapid, complete, and accurate as possible, and should make use of all available information sources. Where possible, fire-control radars should be used to evaluate and track targets reported to the data exchange.

Information Coding - the conversion of radar and evaluation information to the appropriate code and time relationship for insertion to the data exchange. This will include the conversion of target position coordinates from range, bearing, and elevation with respect to the radar to relative ground position and altitude.

Target Data Insertion - the insertion of coded target data to the combat data exchange relay. This will include the mixing of data reports and the transmission to the data exchange transmitter.

At present, the development of adequate means for target selection is considered to be the most difficult problem posed by the data exchange method of combat coordination. An attractive solution appears to be the direct electronic conversion from radar video information to coded target data which can be directly compared with, or added to, the information in the data exchange. The means for implementation of such a solution, however, are obscure.

One method by which automatic detection and tracking under coordination of the data exchange might be achieved is now described. A number of gate circuits are caused to ride along with the search radar coordinates in range, bearing, and elevation. When an echo is received, one gate is dropped at the position of the echo, and its coordinates, in coded form, are fed to a computer. On the next revolution, providing the echo is received within certain dimensions of its initial position, the gate takes up the echo's new position and commences moving at the apparent rate of the echo. The course and velocity of this motion may also be coded and used by the computer for automatic evaluation of the target. Each gate dropped on an echo eliminates the area covered by it from that under surveillance by the remaining gates, while the computer by reference to the data exchange prevents gates from being placed on targets already being reported.

Obviously, this or other methods of automatic target detection and analysis can operate satisfactorily only if MTI and anti-clutter circuits are utilized to remove the majority of fixed echoes. Suggestions for the automatic analysis of radar data by digital computers have been made and it is urged that serious study be given to the development of such computers.

Effective manual procedures for coordinated target selection, evaluation, and reporting are required irrespective of the development of automatons for this purpose. Since each unit will be required to evaluate and report a relatively small number of targets these functions can be performed by relatively standard procedures and equipment. Target selection, however, requires in the general case choice of the most appropriate targets for evaluation and reporting from among several hundred radar echoes. Under these conditions, it is considered that effective manual target selection cannot be performed unless the radar echoes of targets and friends reported in the data exchange are identified, and the local selection of targets for evaluation are indicated in a single presentation. This can be accomplished by the superimposed presentation of appropriate radar, Codaer, and gate indications.

#### CODAER INDICATORS

Two general types of indicators are required for presentation of Codaer information - data indicators for the presentation of the complete data of a single report, and surveillance indicators for the display of selected targets or friends in any two coordinates with provision for the indication of the notation (report channel), identification, type, and other

coordinates such as track or altitude, etc. Both types of indications must be decoded electronically from the data exchange information and should preferably be presented directly upon cathode-ray tubes without the use of mechanical components.

One method which suggests itself for the data indicator is the use of a small-area raster scan which can be switched under the control of the input coding to read words, letters, or figures from an information storage device such as a monoscope or video insertion system. These words, letters, or figures can then be presented in an easily read arrangement on an indicating cathode-ray tube. To generate the potentials corresponding to these symbols, the data will require some form of decoding from the binary base used in the code to the various bases used for indicating the report data. Considerable simplification in the decoding will result from the use of binary coding in groups corresponding to each base 10 figure rather than the binary coding of the whole number. The simplification in decoding will require, however, a small increase in the number of digits and transmission time of a given whole number. When the data, computation, and indication requirements for this system have been established, a detailed analysis of the data coding should be made to determine the optimum form with respect to over-all considerations of reliability, capacity, and equipment economy.

The surveillance indicator is required to display targets and friends for the purpose of manual control and monitoring of particular operations. Codaer data supplied to the indicator will first pass through a selective computer which will select for the display only those targets (or friends) which have the position, type, etc. parameters chosen for the display. The selected targets will then be decoded as to position and data, and presented appropriately on a cathode-ray tube.

The type of data which will generally require presentation on a surveillance indicator will be target position (usually with relation to own ship), track, notation, identification, altitude, and quantity. Determination of position with regard to own ship can probably be performed simply by subtraction of own ship's position from the target's position before decoding. Likewise, the plot might be centered about any position simply by entering the center position to an appropriate computer.

After the coded data on the target's position has been reduced to the desired center coordinates, it can be decoded into position potentials. These potentials will represent the X and Y dimensions away from center and can be used to position the beam of a cathode-ray tube. To present both present position and track of targets, it would seem necessary to use a storage tube — a grapheon, for example — to store successive present position inputs on a number of targets and to read the tracks of each for indication. A television reading scan would seem appropriate here and would permit the external insertion of written and pictorial data.

To insert written notation, altitude, etc. on targets at their present position, methods similar to those described for the data indicator could be used for decoding the target data and presenting it as figures and letters in successive small-area raster scans. By centering these raster scans with the position potentials of the targets and writing them on the screen of a short-memory storage tube, the notation of the targets at their correct position may be read for presentation. With proper centering and synchronization, the same television scan may be used for reading both target notation and track so that the indications are combined in the display.

The target notation itself should be kept to a minimum to prevent overlapping and resultant confusion of targets with small relative separation. Position, course, and speed can be shown roughly by the target's track, while the data channel notation may be made



to show identification and class of target by the use of lower- and upper-case letters. Two-letter notations should serve to identify any one of a maximum of 676 data channels, and further information might be provided in the data channel notation by the specification of certain groups of channels for reporting particular types of targets. The number of targets could be entered ahead of the data channel notation, and the altitude in two figures, for example, in thousands of feet, following it. Investigation into the coding and arrangement of notations should be undertaken to develop means for conveying clearly a maximum of information with a minimum of letters and figures.

The number of targets which can be shown on a single surveillance indicator is limited by the number of notations and tracks which can be presented clearly on a single television raster scan. If all notations were lined up in a manner similar to words on a printed page, roughly 500 notations could be presented. However, since this is an extremely unlikely condition, it will probably be necessary under normal conditions to limit the area or types of targets presented by a single surveillance indicator so that a maximum of 20 to 50 targets are displayed.

For target selection and other operational functions in which both radar and Codaer data must be related, it is necessary to superimpose corresponding radar and Codaer indications. Normally this will involve the superposition of radar PPI and Codaer surveillance indicators having equivalent coverage. One method of superposition would be the conversion of radar information (by means of an appropriate storage tube) to video associated with the television scan used for the surveillance display. Pictorial and gate information for tracking and evaluation of radar targets can also be inserted in the television scan. Providing the superposition of targets is used simply for identification and selection, while tracking and quantitative measurements on specific targets are made from raw radar or Codaer information, great registration accuracy of the different presentations is not necessary. A 5 percent mismatch should be tolerable for most displays.

#### SHAFT POSITION TRANSMISSION AND CODING

The transmission of position information within a ship, for example, is commonly accomplished by synchros and associated servo systems. Combat ships may have several hundred synchros each connected with one or more remote points for the transmission and reception of shaft position information. Since each synchro requires a minimum of three wires in addition to common rotor lines, highly complex wiring and switching arrangements are required to permit flexible interconnection of directors, radars, gun mounts, computers and control stations. To reduce the complexity of the wiring and switching, and at the same time to facilitate the automatic control of switching and insertion of information to the combat data exchange relay, it is suggested that the transmission of position be effected by pulse code methods similar to those proposed for the Codaer system. It should be quite feasible to code in a report interval of 50 microseconds the complete shaft positions, equipment identification, and other pertinent information constituting the normal output of a director, computer, or other equipment. The coded outputs of all related equipments could be entered in a definite time sequence to a single bus line, which would then form an internal data exchange.

Assuming a one-wire data exchange bus between all related equipments, the interconnection of any two equipments would simply be a matter of adjusting the timing of input selectors so that only the desired information is passed on to decoding and servo circuits. This is a function which can readily be performed by electronic circuits. The objection may be raised that this method of data distribution will be less reliable than standard synchro transmission because of its dependency on electronic circuits. The

critical timing selector components, may, however, be made extremely reliable by use of off-on type counting circuits and other techniques so that such objections are largely invalidated.

To replace synchros as the basic component for measurement and transmission of shaft position will require the development of special devices for pulse coding of shaft position. One method for converting shaft position to a pulse code of given timing is to use a CRT flying-spot scanner reading an optically coded wheel connected to the shaft. In any case, a major effort should be directed towards the development of reliable, compact, and simple devices for converting shaft position to appropriate pulse coding, for these components will ultimately determine the accuracy to which information can be handled by pulse code methods.

### OPERATIONS CONTROL

Information on the activity and location of all friendly and enemy craft will be presented sequentially in coded form by the Codaer system to operations control equipment. This equipment must evaluate and select targets, decode and indicate the information selected, and initiate appropriate action. All phases of the automatic operations control must be under manual monitoring and supervision. In general, it is believed that appropriate electronic computers can provide automatic operations control, while monitoring and supervision may be exercised by reference to various combinations of data and surveillance indicators.

Electronic digital computers of various types should be capable of performing any control or command function that can be formulated in terms of the tactical situation as presented by the Codaer information and the parameters of the weapons or elements under control. Combat operations for which mechanization is indicated include AA fire coordination, air intercept control, air traffic control, etc. The computational processes required for control of these functions are primarily those of evaluation, selection, and order generation. Normally, evaluation and selection will require the calculation of a score and a Yes-No decision for each target or friend reported in the data exchange. Since a data report occupies only about 50 microseconds, these calculations must be exceedingly rapid, and new techniques may be required. The computations will be relatively simple, however, and with proper coding, no particular difficulty is foreseen. Order generation computers will ordinarily make calculations based on one or at most two selected reports and may, therefore, store information which cannot be utilized instantaneously.

Operations control equipment may be located on any ship, plane, or ground facility. In all cases it will be provided with the most complete tactical information available through the Data Central transmission. Evaluation and selection components will provide information and control of operations by utilizing that portion of the tactical data which is pertinent to the particular operation. Planes, for example, might carry intercept control equipment which, in addition to calculating the intercept course, could automatically select and display the most appropriate targets for interception. Thus, the duty of intercept controllers might be reduced to monitoring and coordination of intercepts rather than continuous direction of all flights.

### AA FIRE COORDINATION

The concept of a combat data exchange relay and its many ramifications have been developed in the process of a search for an adequate solution to the naval air defense

problem. This problem is so fundamentally interconnected with all phases of information, communications, and operations control that it has seemed impossible to even propose a potentially effective system for mechanization of the air defense functions without also recommending the mechanization of the related departments. The development of a single system for the rapid collection and distribution of tactical information provides a framework into which all types of operations control equipment may be fitted and coordinated.

The computational processes involved in AA fire coordination from Codaer information are basically those of evaluation and selection. A preliminary analysis indicates that the following functions must be performed:

Target Evaluation - the determination of relative threat of each target to own ship. For this function a computer must determine the relative threat of each target from its position, motion vector, type, counteraction status (the action taken against the target by other ships or planes) and any other information contained in the Codaer data on the target. The output of the target evaluation computer should be the input data with the addition of the relative threat score of each target. It will probably be found desirable to have this computer select for further immediate action only those targets within acquisition range of the ships' radars. The parameters for weighting of target threat and for target selection should be under the control of a monitoring officer.

Director Selection - the selection of the most appropriate director for each target. The output of the target evaluation computer will be fed to a set of inter-connected director selection computers. One of these computers will be associated with each director, and the selection parameters of each will be determined by the characteristics of the associated director. The selection parameters will include director range, sector coverage, and relative priority in the various portions of its sector coverage, types of weapons controlled, relative performance, status of action, etc. The selection computers simultaneously receive the data on each target and evaluate the suitability of each director for tracking that target. The director whose computer makes the highest score on its suitability for tracking a target will be assigned that target. Having selected a particular target for its director, the computer will store the relative threat value of the target as received from the target evaluation computer as a reference to compare with other targets on which it may make the highest suitability score. If a computer makes the highest suitability score on a target of greater threat than one already assigned to its director, it will re-assign the director to the target of greatest threat, subject to the status of counteraction against the target previously assigned. The counteraction status might well be given a numerical value and added to the reference threat value of an assigned target, so that a new target must be of much greater actual threat than one being tracked, for example, to cause reassignment of the director.

In the selection of targets, they will be presented to the selection computers at a repetition rate of about 30 times per second. Since no appreciable action can be taken by a director in less than a second, there will be ample time for targets to be assigned strictly on the basis of their relative threat and the suitabilities of the various directors before counteraction status can effect the choice of targets.

Assignment of a target to a director will consist simply in gating out from the Codaer information the data for a particular target. This data will then be transmitted to the equipment at the director which will decode the information, compute the target's range, bearing, and elevation from its ground position and altitude, and cause the director radar to search about this point in space.

Friend Protection - the protection of friends from own force fire. This can be accomplished automatically by a computer which scans the Codaer data on all friendly units to determine if any are close to the line of sight or position of targets being taken under fire. If friends are found within certain dimensions of the line of fire, the weapons assigned to the target will be prevented from firing.

Weapon Selection and Fire Distribution - the selection of the most appropriate weapons to use against specific targets, and the distribution of fire in such a manner as to insure a maximum chance of own ship survival. Weapon selection may be accomplished by computers similar to those described for director selection. Inputs for the weapon selection might be either the target data assignments to the directors or coded present position and evaluation outputs from the directors. Fire distribution control may be exercised through the weapon selection parameters which determine the choice and number of weapons to be assigned to each target.

#### INTERSHIP PLOTS

A system of intership plots can provide on a manual level very great improvements in the efficiency of the information and command departments of the individual ships of a task force. Such a system can effectively integrate the manual plotting and evaluation functions of all ships so that the number of targets which may be appropriately plotted and evaluated will increase in proportion to the number of associated ships.

In the present proposals for automatic combat coordination based on the rapid exchange of tactical data in coded form, the necessity for manual coordination of most operations through interunit plots no longer exists. A plot or pictorial exchange associated with the coded data exchange may, however, prove very desirable as a secondary method for monitoring and manual control of operations, and as a supplement to standard communications facilities. In particular, the presentation to commands of filtered plots showing the general deployment and activity of all forces, and the distribution of televised scenes should be facilitated by an interunit plot exchange.

The methods by which a plot exchange can be effected are essentially the same as those required for the data exchange relay. A single Data Central is required to synchronize, receive, and mix the contributions of each associated unit, and to transmit the complete plot to all units. Units contributing to the composite plots will be required to measure their range and bearing from the Data Central and to advance the synchronization received from the Data Central by the two-way transmission time in order to enter information to the plots correctly. If, as suggested, the report interval for the coded data reports is made the same as that required for a television line, the same synchronizing circuit could be used for both plot and data exchanges.

## RELAY LINKS

The Codaer system requires that each combat unit receive the general transmission from the area Data Central and report back its location, activity, and any tactical information it may have gathered on enemy forces. In addition, certain types of ships, planes, or ground facilities must be equipped to function as an area Data Central. In general, report transmissions from individual units to the Data Central may be beamed by directional antennas and should require very low power, while transmissions from the Data Central to all units cannot be beamed and, therefore, will require high power. To minimize antenna dimensions, and to limit the range of the transmissions, the use of microwaves seems logical. Two, 4-6 megacycle bands will be required for the coded data transmission, and two more for each plot transmission.

The relay links required for the Codaer system are very similar to those being employed commercially for relay of television broadcasts and corresponding techniques should be applicable. Severe limitations will probably be placed on the size of directional antennas to be used in planes and other small craft. It is to be hoped that it will be possible to develop a broadband directional antenna and associated filter circuits which will permit simultaneous reception and transmission of data and plot signals.

## SYSTEM EVALUATION

The intention of this report is to present for consideration a general system for coordinated mechanization of the combat functions of an air-sea-land task force. The achievement of mechanization on this scale will be a tremendous task, irrespective of the methods to be used, and can be implemented in a reasonable period of time only through the combined efforts of many research activities. It is urged that evaluation of a few methods for systematic mechanization of tactical operations be undertaken as rapidly as possible, so that within a few years it will be possible to concentrate research and development effort on the design and production of a single system for this purpose.

Evaluation of the present proposals will require both the development of the basic techniques and components essential to the performance of the various intelligence, communications, and operations control functions, and the analysis and specification of combat functions in terms of the tactical data which will be furnished the control equipment. The preliminary technique and component research must provide practical solutions to all phases of the proposals, and will, therefore, require considerable effort. Among the initial investigations indicated are the following:

1. Analysis of the data medium and its utilization by electronic computers.
2. Development of indicators for displaying the coded information.
3. Development of devices for conversion of shaft position to coded data and vice-versa.
4. Development of the basic components and features of the combat data exchange relay. Special emphasis must be placed here on the automatic reporting by each craft of its position, activity, and information on enemy activity.
5. Development of a system for coordinated target selection, evaluation, and reporting by radar systems on different units.
6. Development of computing devices for utilizing Codaer information for AA fire coordination, air intercept control, and other operations for which mechanization is indicated.
7. Investigation of the suitability of an intraunit data exchange for replacing synchro data transmission.

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